

CLINICAL BALANCE ASSESSMENTS FOR OLDER ADULTS:
AN ANALYSIS OF COGNITIVE FUNCTION

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ABSTRACT

STEPHANIE BOMBERGER: Clinical Balance Assessments for Older Adults:
An Analysis of Cognitive Function
(Under the Direction of Bonita L. Marks, Ph.D.)

In the elderly, functional decline is most often diagnosed with performance assessments for physical function without any neuropsychological testing. **Purpose:** To investigate the relationship between cognitive function and physical performance assessments in elderly volunteers. **Methods:** Age-adjusted linear and multiple regressions were run between assessments of cognitive function (Symbol Digit Modalities Test) and balance (Single-Leg Stance Test, SLS; Tandem Stance Test, TS; Four Square Step Test, FSST), mobility (Gait Velocity from the 10-Meter Walk Test, 10MWT), and strength (Timed Chair Rise Test, TCR). **Results:** Independent of age, nearly 28% of SDMT scores were uniquely explained by FSST ($r_{\text{part}} = 0.278$, $p = 0.002$) and Gait Velocity ($r_{\text{part}} = 0.253$, $p = 0.005$). None of the other variables attained statistical significance. **Conclusions:** In the clinical setting, FSST and Gait Velocity can be used to gather information regarding both physical and cognitive functionality in elderly individuals.

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LIST OF ABBREVIATIONS

10MWT - 10-Meter Walk Test

ADL - Activities of Daily Living

AGS - American Geriatrics Society

BGS - British Geriatrics Society

FSST - Four Square Step Test

PPFOP - Panel on Prevention of Falls in Older Persons

SLS - Single-Leg Stance Test

SDMT - Symbol Digit Modalities Test

TS - Tandem Stance Test

TCR - Timed Chair Rise Test

TUG - Timed Up and Go Test

WHO - World Health Organization

CHAPTER I

The Problem

Introduction

In an aging individual, decreased functionality of the physiological systems necessary for postural control is an underlying concern for balance-related falls risk (Tinetti, Speechley & Ginter, 1988). Age-related physiological changes in the eyes, inner ears and proprioceptive systems directly impact the quantity and quality of sensory information available (Guccione, Wong & Avers, 2011). These changes can significantly alter the ability to process and respond to the sensory information and also have a direct impact on the static and dynamic balance ability in an older adult (Guccione et al., 2011). As a result, the risk for falling increases substantially once these systems begin to decline due to normal process of aging or disease (PPFOP, AGS & BGS, 2011).

A fall is an event that results in an individual coming to rest inadvertently on the ground or other lower level (WHO, 2010). An unintentional fall has the potential to have numerous detrimental effects on the functionality of an individual. One-third of adults ≥ 65 years of age fall annually, and injuries incurred from those falls can result in a general decline in health status and increased mortality rates (Hausdorff, Rios & Edelberg, 2001). In addition to injuries resulting from a fall, the psychological changes that can occur following the event may further increase fall risk (Vellas, Wayne, Romero, Baumgartner & Garry, 1997a). As a result, the implications of a fall on the individual, family and community can be costly, especially when compounded by the sizable prevalence of these events in society. The

economic impact of falls has been estimated to amount to billions of dollars worldwide (Stevens, Corso, Finkelstein & Miller, 2006).

In response to the high prevalence of falls and the injuries and/or deaths incurred, there has been an abundance of research aimed at assessing, preventing, and treating the factors that contribute to fall risk. Risk factors for experiencing an unintentional fall are categorized as extrinsic, intrinsic, or a combination of the two (McVey & Studenski, 1988; Tinetti & Speechley, 1989). Extrinsic risk factors are those that are a result of the environment, such as flooring surfaces, obstacles, and/or external perturbations. An intrinsic risk factor is directly attributable to the health status of the individual. Tinetti et al. (1988) asserted that the most important intrinsic risk factors for experiencing a fall were sedative medications, cognitive decline, lower body strength, and poor balance. Falls related to decreased balance ability involve the interaction of declining lower body strength, gradual sensori-motor degradation, and cognitive dysfunction.

Statement of the Problem

Deficits to one's balance, mobility, muscle strength, and cognition are among the risk factors for experiencing a fall (Lord, Clark & Webster, 1991; PPFOP et al., 2011; Tinetti et al., 1988). In the clinical setting, physical therapists and other healthcare providers use validated functional performance tools to quantify balance, mobility and strength; however, a patient's cognition is often left untested (T. E. Shubert, personal communication, June 30, 2011). The processing speed and executive control aspects of cognitive function contribute to sensorimotor function, and are considered predictors of falls, poor balance, and slow walking speed in elderly individuals (Lord et al., 1991; Lord, Lloyd & Li, 1996; Salthouse, 1996). When compared to an individual with normal cognitive function, an individual with poor

cognitive function may perform worse on a balance or mobility assessment, as well as respond differently to an intervention, and may not have the desired improved functional outcome to balance and mobility training (Hauer, Lamb, Jorstad, Todd & Becker, 2006b; Jensen, Nyberg, Gustafson & Lundin-Olsson, 2003). *Therefore, the purpose of this study was to contribute additional information to the existing falls prevention literature by investigating the relationship between cognitive function via the Symbol Digit Modalities Test (SDMT) and functional performance (balance, mobility, strength) in elderly volunteers residing independently in the community.*

Research Questions

Research Question 1: Does a relationship exist between performance on clinical balance assessments and a cognitive assessment?

This question had the following three specific components:

RQ 1a: Does a relationship exist between performance on the SDMT and Single-Leg Stance Test (SLS)?

RQ 1b: Does a relationship exist between performance on the SDMT and Tandem Stance Test (TS)?

RQ 1c: Does a relationship exist between performance on the SDMT and Four Square Step Test (FSST)?

Research Question 2: Does a relationship exist between performance on clinical mobility assessments and a cognitive assessment?

This question had the following specific component:

RQ 2a: Does a relationship exist between performance on the SDMT and Gait Velocity?

Research Question 3: Does a relationship exist between performance on clinical strength assessments and a cognitive assessment?

This question had the following specific component:

RQ 3a: Does a relationship exist between the performance on the SDMT and Timed Chair Rise Test (TCR)?

Definition of Terms and Abbreviations

1. Cognitive function – the process(es) by which an individual retrieves, processes, stores, and accesses information (Lezak, 2004).
 - 1a. Executive function – the process(es) associated with goal oriented actions; attention, memory, and motor skills; abilities decline with the deterioration of the frontal cortex seen in aging and conditions such as dementia.
 - 1b. Processing speed – the rate that the brain integrates information; faster processing speed indicates more efficient thinking and learning.
2. Dynamic balance – maintenance of postural control during a moving activity (such as walking; Shumway-Cook & Woollacott, 1995).
3. Functional mobility – ability to perform everyday activities that require dynamic and static balance (Podsiadlo & Richardson, 1991).
4. Static balance – maintenance of postural control during a stationary (non-moving) activity (Shumway-Cook & Woollacott, 1995).

Delimitations

In order to reduce the chances of having confounding variables affect the relationship between scores on physical and cognitive performance assessments, the target population was delimited to only include elderly individuals (≥ 65 years old) who had no known

neurological condition or terminal disease, had no visual impairment that could not be corrected by corrective lenses, were able to read, hear, and understand English, and were able to follow a three-step command.

Limitations

The limitations of this study included the use of self-report questionnaires, as well as the reduced generalizability of the study findings due to the inclusion and exclusion criteria, as noted in “*Delimitations*.” The self-report questionnaires were used to collect medical history and demographic information from the subjects. They were reviewed with the subjects by trained researchers in order to clarify responses and reduce inaccuracies.

Assumptions

1. All subjects answered honestly and accurately on all questionnaires, and performed to their highest abilities on all physical and cognitive performance assessments.
2. All research testing personnel conducted the tests accurately and were inter-reliable in their testing and scoring techniques.

Significance of the Study

Identifying which balance, mobility and/or strength tests require contribution from an individual's cognition may enable clinicians to better diagnose balance and mobility deficits that are cognition-dependent. Practical applications of the findings include aiding clinicians in appropriately prescribing intervention protocols that will be most efficacious for reducing a patient's specific falls risk.

CHAPTER II

Review of Literature

Introduction

Risk factors for experiencing a fall include deficits to cognitive and physical function. Maintaining postural control is a complex skill requiring the ability to receive and integrate sensory information, as well as initiate a coordinated motor output (Berg, K., 1989). Therefore, an individual with impaired executive function and processing speed may exhibit poor balance and be at a higher risk of falling. In addition, individuals with impairments to cognitive processes may have a different response to conventional balance training programs. In a physical therapy setting, a patient's physical performance is typically assessed prior to developing and prescribing an intervention to reduce fall risk. Cognitive assessments are rarely, if ever, performed (T. E. Shubert, personal communication, June 30, 2011). Determining the balance, mobility, and strength assessments that require the greatest contribution from cognitive function could improve the quality of information available to clinicians assessing and treating older adults with cognitive impairments.

Balance

Balance is a complex, multifaceted construct which requires integration of sensory inputs (vision, vestibular, proprioceptive, etc.) and a coordinated motor output. Achieving balance, or equilibrium, is necessary for postural control and maintaining body position in space (Pollock, Durward & Rowe, 2000). In most situations, postural control mechanisms work

subconsciously to maintain the body's center of gravity (also, center of mass), over the base of support (Berg, K., 1989).

In the clinical setting, balance ability is typically assessed as static (stationary) or dynamic (moving) (Shumway-Cook & Woollacott, 1995). K. Berg (1989) suggested describing balance in terms of function using the following dimensions: maintenance of a static position, postural adjustment to voluntary movements, and reaction to external disturbances. Evaluating sensory input is necessary for understanding the mechanisms for maintaining, achieving or restoring balance and postural control, however it is still important to differentiate between static and dynamics conditions.

Sensory input required for maintaining balance.

The sensory systems responsible for balance and postural control are the visual, somatosensory, and vestibular systems. The visual system provides information regarding the body's orientation and position in space. This can be described as assessing how "level" an individual is with respect to a known plane (e.g. the horizon). The somatosensory system provides information regarding the orientation and position of body segments by receiving information from joint, cutaneous, and proprioceptor receptors; these receptors respond to pressure and tension on the skin, tendons, and muscles. The vestibular system, located in the inner ear, is responsible for determining the position of the head with respect to gravity. In addition, the vestibular organs provide input with respect to the speed and acceleration of head movements in the frontal, sagittal, and transverse planes (Shumway-Cook & Woollacott, 1995).

Typically, the visual and somatosensory systems provide the majority of input necessary for maintaining balance. However, during a situation in which a conflict in these systems

arises, the vestibular system is able to resolve inconsistencies to achieve or restore balance (Black, Wall & Nasher, 1983). For example, an event in which the visual system provides information that the body is not level with respect to the environment, but the somatosensory system reports that the body segments are appropriately positioned, the vestibular system would provide information regarding the head's position with respect to gravity, and resolve the conflict in sensory information. Another example of conflict resolution for sensory information would be a situation in which an individual is stationary but the objects around the individual are moving. The visual input would suggest to the brain that the person is moving, however, the proprioceptive and vestibular systems would correct the miscommunication.

Balance and Falls Risk: Causes and Consequences

A “fall” is defined as an unintentional change in body position resulting in coming to a rest on a lower level (WHO, 2010). Older adults are at a heightened risk for experiencing a fall due to the age-related deterioration of many of the physiological systems necessary for maintenance of balance and posture (Lord & Sturnieks, 2005; Shumway-Cook & Woollacott, 1995). An estimated one-third of elderly adults (≥ 65 years old) will fall annually, and the prevalence of fatal and non-fatal falls increases with age beyond 65 years (Hausdorff et al., 2001; Stevens et al., 2006). In a meta-analysis of national health statistics, Stevens et al. (2006) determined that 10,300 fatal falls occurred in 2000, amounting to \$179 million in direct and indirect medical care costs. An estimated 2.6 million injurious, non-fatal falls occurred, resulting in a total annual medical cost of \$19 billion (Stevens et al., 2006).

W. Berg, Alessio, Mills and Tong (1997) monitored the prevalence, circumstances, and consequences of falls in 96 male and female individuals over the age of 60 and living

independently in the community. Over the duration of the 12 months of data collection, 52% of the participants experienced at least one fall, amounting to a total of 91 falls. This fall rate exceeds the rate of 33% often reported in the literature (Hausdorff et al., 2001).

According to W. Berg et al (1997), falls were likely to occur while moving (59%), at home (58%), and alone (63%). Individuals fell more often during the afternoon hours and during the winter months. Participants described the falls that occurred while moving as “trips” (34%) and “slips” (25%), which is comparable to the causes noted in similar studies by other research groups (Cumming & Klineberg, 1994; Hill, Schwartz, Flicker & Carroll, 1999; Topper, Make & Holliday, 1993).

After experiencing a fall, an individual is at a high risk for functional decline. The decreased function, if not caused by an injury incurred during the fall, is likely caused by the limitation of daily activity due to a fear of falling. Vellas et al. (1997a) assessed the relationship between fear of falling and activity restriction in individuals who had experienced a fall. When asked if individuals were “worried about falling again”, 32% of previous fallers responded “yes”. The individuals who expressed fear of falling were more likely to develop balance abnormalities and cognitive impairments than those who did not express that fear. In a follow-up analysis, fallers also exhibited deficits to their physical health status and mobility, in addition to the cognitive and balance impairments previously reported (Vellas, Wayne, Garry & Baumgartner, 1998).

Risk factors for experiencing a fall.

Shumway-Cook and Woollacott (1995) presented a systematic approach to assessing decreased balance ability or “postural dyscontrol”. According to their approach, the lack of

postural control and subsequent instability is the result of impairments to the neuromuscular, musculoskeletal, cognitive/behavioral, and/or sensory/perceptual systems (see Figure 1).

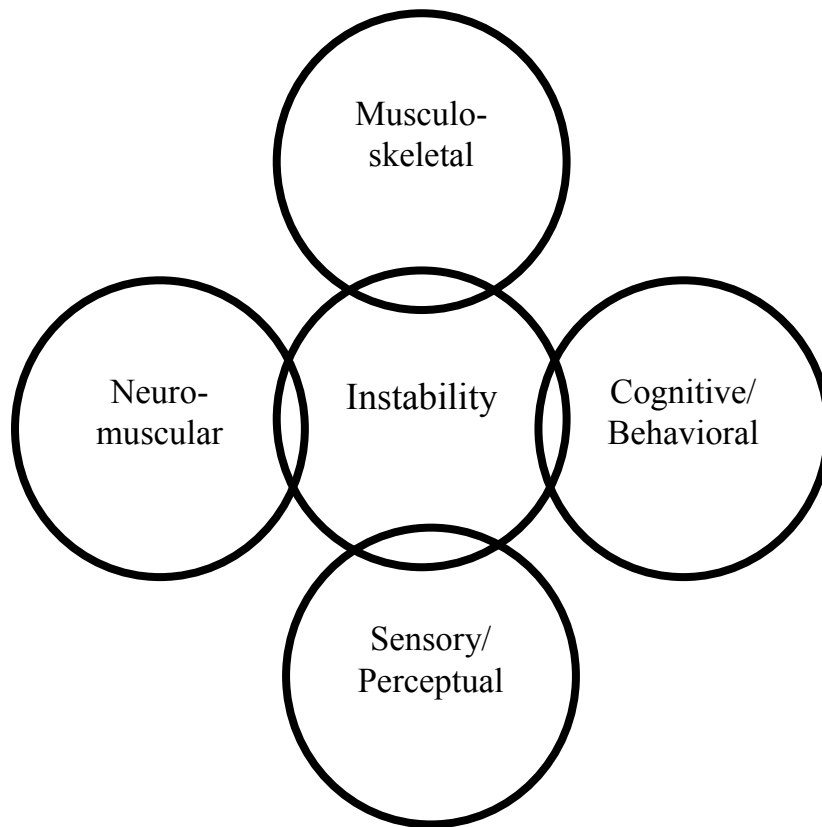


Figure 1. Systematic approach to assessing impairments that influence postural dyscontrol and instability in human balance.

Impairments to the musculoskeletal, neuromuscular, sensory and/or cognitive systems all influence the postural control and can result in instability.

Adapted from “Motor Control: Theory and Practical Applications” by A. Shumway-Cook and M. Woollacott, 1995, Baltimore, MD: Williams & Wilkins, p.187.

In normal aging processes, a degradation of sensory systems occurs and is a major contributor to declining stability and the increased fall risk seen in elderly adults. According to Shumway-Cook and Woollacott (1995; see also 2000), the somatosensory, visual and/or vestibular systems experience a decrease in functionality over time. Multisensory deficit, or the impairment of multiple sensory systems, results in the lack of ability to compensate for

impairment to any one system due to the significant lack of functionality in many or all sensory inputs required for balance control.

The somatosensory system, specifically cutaneous vibration receptors, is often affected by neuropathy, or a lack of sensation, and does not respond to changes in vibration or pressure. The visual system experiences a normal decrease in visual acuity over time, partially due to the changes in light receptor function with age. An analysis of fallers in a Liverpool geriatric unit revealed that half (50.5%) of the admitted patients had a significant visual impairment (Jack, Smith, Neoh, Lye & McGalliard, 1995). Of the types of impairments, corrective refractive errors, cataracts and senile macular degeneration were the most notable. A majority of patients with a visual impairment also had experienced a fall (76%). Within the vestibular system, a decrease in functionality is caused by the degeneration of hair cells (Shumway-Cook & Woollacott, 1995). These cells are located along the inside of the semicircular canals of the vestibular organs in the inner ear. They inform the central nervous system of any movements of the head with respect to gravity. By 70 years of age, the number of hair cells can decrease by up to 40% (Shumway-Cook & Woollacott, 1995).

Tinetti et al. (1988) conducted a 12-month prospective study of a large cohort of elderly individuals living in the community in which information was collected regarding general health and falls. They identified predisposing factors associated with experiencing a fall, noting that the risk for falling increased exponentially with the number of factors an individual expressed. Sedative use and impairments to cognition, lower extremity function, gait, and balance were identified as the top risk factors. An individual with four or more risk factors was 78% more likely to experience a fall than an individual with no risk factors.

Additionally, the study revealed that nearly half of the falls occurred while the individual was exposed to environmental hazards.

In 2010, an updated guideline for falls risk assessment was developed and published by the Panel on Prevention of Falls in Older Persons (PPFOP), American Geriatrics Society (AGS), and British Geriatrics Society (BGS). Assessing a detailed history of falls, medication use, and general health, as well as quantifying neurological function, balance, mobility, and strength were the evidence-based standard of care recommended. The update noted that older adults' homes should be evaluated when assessing fall risk and determining methods for effective prevention of falls (PPFOP et al., 2011).

Cognitive aspect of balance ability.

A result of the wide range of functions controlled by higher brain centers is that deficits to cognition can have a significant impact on an individual's daily life. The cognitive function for postural control integrates sensory input from the peripheral somatosensory receptors and coordinates motor output. In two separate studies, researchers demonstrated that executive function and processing speed were associated with both gait and falls (Holtzer et al., 2007; Holtzer, Verghese, Xue & Lipton, 2006). They also demonstrated memory and verbal IQ were associated with gait speed in healthy aging individuals (Holtzer et al., 2006).

In 2000, Shumway-Cook and Woollacott determined that limited sensory information availability, as seen with the sensory system degradation that occurs due to the normal process of aging, increased the attentional demands of normal walking and functioning. Therefore, if an individual is unable to devote enough attention and concentration to a

walking task, they may experience decreased postural control and be at increased risk for a fall.

Clinical Assessments

As noted by the updated falls prevention guidelines (PPFOP et al., 2011), a complete assessment of fall risk includes collecting medical history, current health status, falls history, and living conditions, as well as testing the individual's balance, mobility, strength, and cognition. Although international guidelines support a multi-factorial approach to falls risk management, Lord and Sturnieks (2005) reported that the most common clinical strategies included assessing strength, stability and mobility in static and dynamic conditions. The physical assessments for evaluating static balance, dynamic balance, mobility, and strength are detailed below. Few, if any therapists routinely assess cognition, even though processing speed and executive function abilities have been linked to mobility impairments and falls risk (Holtzer et al., 2007; Holtzer et al., 2006).

Physical performance assessment measures: balance, mobility, strength.

Single-Leg Stance Test (SLS) and Tandem Stance Test (TS) as assessments of static balance ability.

The Berg Balance Scale (BBS) incorporates the SLS and TS into the 14-item balance assessment (Berg, K., Wood-Dauphinee, Williams & Gayton, 1989). The TS is also included in a battery of physical performance tests used in the *Established Populations for Epidemiologic Research in the Elderly* as an assessment of static balance ability (Guralnik et al., 2000). Each test requires the subject to stand quietly on a narrow base of support (one supportive leg during SLS, or in a tandem stance with one foot directly in front of the other for TS) for as long as possible. During development of the BBS, K. Berg et al. (1989)

demonstrated that the SLS and TS were each reliable between raters and over multiple assessments (inter- and intra-rater reliability ICC = 0.98 for SLS and TS).

Vellas and colleagues (1997b and 1998) demonstrated that a cut-off score of 5 seconds was related to a higher risk for experiencing a fall in elderly men (relative risk = 2.01) or an injurious fall in elderly women (relative risk = 2.97). Similarly, a 10-second cut-off score for the TS was associated with a decrease in functional mobility and balance (Berg, K., 1992; Buchner et al., 1993).

The Timed Up and Go Test (TUG) as an assessment of dynamic balance and mobility.

The TUG test is a timed test in which an individual is observed and timed while safely performing the following tasks in order:

1. Rise from a seated position in a standard-height chair;
2. Walk three meters;
3. Turn around and walk back to the chair; and
4. Return to a seated position in the chair.

Based on validation by Podsiadlo and Richardson (1991), the TUG is a reliable measurement device and indicative of functional mobility in elderly individuals. According to Shumway-Cook, Brauer and Woollacott (2000), the assessment demonstrates 80% sensitivity and 100% specificity when used as a predictor of falls in elderly individuals (cut-off score = 13.5s; predictive probability = 0.77).

Four Square Step Test (FSST) as an assessment of dynamic standing balance.

The FSST assesses an individual's dynamic standing balance through a stepping and direction-change exercise. Dite and Temple (2002) developed and validated the assessment in response to the high prevalence of falls that occur during situations which require rapid

stepping in multiple directions. The assessment requires subjects to step through a series of boxes which have been marked off by canes on the floor (see Figure 2). Subjects step forward, sideways, and/or backward over the canes from each box to the next as quickly and accurately as possible (Appendix G; Dite & Temple, 2002).

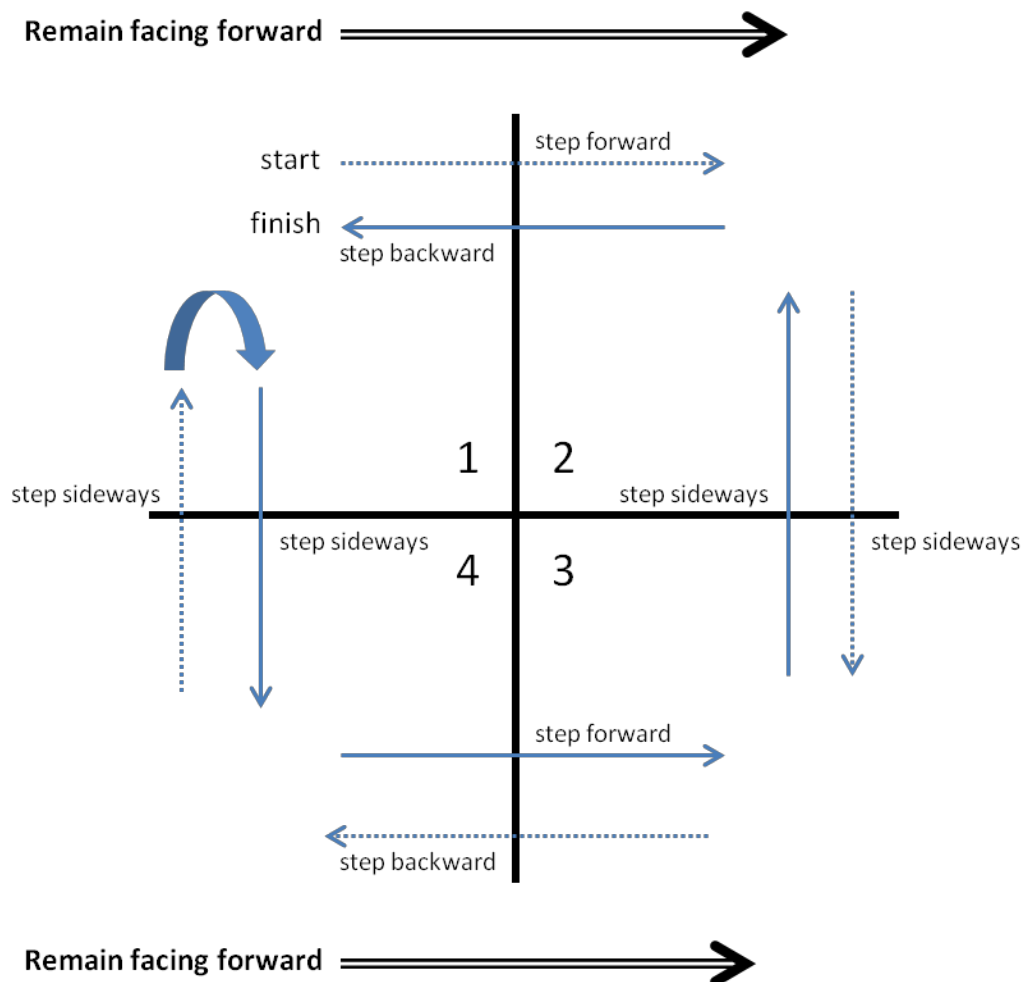


Figure 2. Diagram of FST obstacles and stepping pattern.
Adapted from “A Clinical Test of Stepping and Change of Direction to Identify Multiple Falling Older Adults” by W. Dite and V. A. Temple, 2002, Archives of Physical Medicine and Rehabilitation, 83, p.1568.

During validation of the instrument, Dite and Temple (2002) verified a cutoff of 15 seconds to identify multiple fallers with the FSST. The test demonstrated high test-retest reliability (ICC = 0.98) and inter-rater reliability (ICC = 0.99), as well as an 85% sensitivity for correctly identifying multiple fallers and an 88% specificity for correctly identifying non-multiple fallers. The final analyses revealed an 86% positive predictive value for identifying multiple fallers (task completion > 15 seconds) and 94% negative predictive value for identifying non-multiple fallers (task completion < 15 seconds).

The authors acknowledged that this balance assessment incorporates many aspects necessary for postural control, in addition to dynamic standing balance. The FSST requires lower extremity strength and coordination as the subject must be able to completely transfer weight from foot to foot and clear the height of the cane on the floor to step to the next box. Additionally, remembering the stepping sequence has a cognitive component that may not be present in other balance assessments (Dite & Temple, 2002).

A walking test, such as the 10-Meter Walk Test (10MWT), as an assessment of mobility.

The 10MWT is an easily administered assessment of an individual's gait. The outcome variable, Gait Velocity (in meters per second, m/s), is often used as a measure of mobility (Scivoletto et al., 2011). The 10MWT can be performed using a "static start" or a "dynamic start." During a "static start," subjects initially stand in a stationary position at a starting line, begin walking at the command of the tester, and walk until they reach the 10-meter mark. The "dynamic start" 10MWT requires subjects to begin walking in a 2-meter "acceleration zone". The researcher begins timing the subject when he or she crosses the starting line and continues timing for the 10-meter course. Following the 10-meter mark (or finish line), there

is a 2-meter deceleration zone in which the subject may slow down. According to Scivoletto et al. (2011), both forms of the 10MWT have been demonstrated to have excellent inter-and intra-rater reliability (ICC = 0.95-0.98; ICC = 0.98-0.99). Results of the dynamic and static start methods also showed comparable results (ICC = 0.98-0.99).

Guralnik et al. (2000) analyzed many commonly-used physical performance assessments for the ability to predict functional decline and disability in elderly populations. The findings suggest that performing a walking trial in order to determine self-selected walking velocity is an appropriate method for predicting loss of functional mobility and disability in activities of daily living (ADL). Individuals who self-select a walking speed slower than 1.0 m/s are at a higher risk for experiencing this decline in physical function during the four years following the analysis.

The Timed Chair Rise Test (TCR) as an assessment of lower extremity muscular strength and endurance.

The TCR assesses lower extremity muscle strength and endurance, and requires input from the visual system and proprioceptive system (Guralnik et al., 1994; Guralnik et al., 2000; Lord, Murray, Chapman, Munro & Tiedemann, 2002). The test requires the individual to rise from a standard-height chair (seat height 43.2-cm from the ground) without the use of his or her arms. If successful, the subject repeats the chair rise five times. If unable to complete the five chair rises in 13.6 seconds, an individual is at risk for increased disability and morbidity (Guralnik et al., 2000). Gill, Williams and Tinetti (1995) reported that the inability to complete the TCR in 30 seconds assessments indicated a 30-50% risk for developing functional dependence or disabilities in one or more of the basic ADLs; (See also Gill, Williams, deLeon & Tinetti, 1997; Gill, Williams, Richardson & Tinetti, 1996).

A cognitive assessment for determining executive function and processing speed.

The SDMT is a robust indicator of neurological and psychological function, and specifically assesses executive control, processing speed, and attention (Smith, 1982). The test requires individuals to correctly pair and write (or speak) the appropriate digit with a given symbol over a 90-second time period (see Figure 3).

KEY								
⏏	>	Δ	×	≡	●	+	!)
1	2	3	4	5	6	7	8	9

≡)	●	≡)	+	>	Δ	●	⏏	+	!	×	>

Figure 3. Sample reference pairings and blank SDMT assessment. Each assessment includes a “Key” with nine reference symbol-digit pairs and the assessment with blank spaces where subjects are meant to correctly identify and write the digit associated with the given symbol. There are 110 total pairs to be matched during the 90-second test. Adapted from “Symbol Digit Modalities Test (SDMT): manual (revised)” by A. L. Smith, 1982. Copyright 1982, Western Psychological Services.

The test can be administered using a paper and pencil method or orally, however, the written form requires a higher level of visual acuity. The SDMT has a test-retest reliability of 0.74 (Lezak, 2004). Normative data has been published in various psychological assessment manuals and indicates that scores on the SDMT trend downward with age (Lezak, 2004; Strauss, Sherman & Spreen, 2006). In 2006, Sheridan et al. published the aggregate means

across sex for the written version of the SDMT. According to their findings, adults over the age of 55 years old scored 35.8 ± 9.6 out of the possible 110 points on this cognitive assessment (see Table 1).

Table 1.

Normative SDMT data from previous research.

Age Group		SDMT Score (Mean \pm SD)	
		Written	Oral
Young Adults	< 30 years old ^a	58.2 ± 9.1	69.4 ± 10.6
Middle Adults	30-55 years old ^a	53.2 ± 8.9	59.5 ± 9.2
Older Adults	> 55 years old ^a	35.8 ± 9.6	47.3 ± 11.0
	64-70 years old ^b	33.5 ± 9.4	-
	70-74 years old ^b	27.9 ± 10.3	-
	75-79 years old ^b	26.5 ± 8.6	-
	80-83 years old ^b	20.2 ± 8.7	-

^a Aggregate mean SDMT scores for age groups calculated by Sheridan et al. (2006).

^b Normative SDMT scores for sub-groupings of the older adult age group published by Nielsen, Lolk and Kragh-Sorensen (as cited in Sheridan et al., 2006).

Smith (1982) reported that scores 1.0-1.5 standard deviations (SD) below the mean score for a given age range are “suggestive” of cognitive impairment, and that scores beyond 1.5 SD’s below the age norm are “indicative” of cognitive impairment. Using these cut-off values, the SDMT was able to correctly identify 86% of individuals with confirmed cognitive dysfunction and 92% or normal, healthy controls.

Holtzer and colleagues (2006; 2007) employed a similar substitution task to assess the processing speed and executive function associated with walking and fall risk. Cognitive function, determined by a battery of neuropsychological tests that included the Digit Symbol

substitution task, was used as a predictor for Gait Velocity. The results of the analysis revealed a significant regression between neuropsychological measures and Gait Velocity ($R^2 = 0.162$, $p < 0.05$). Executive function and processing speed contributed the most to the prediction of Gait Velocity ($R = 0.281$) in the model (Holtzer et al., 2006). To date, it appears that no studies have predicted cognitive function from physical performance measures, such as Gait Velocity.

Conclusion

It is evident that postural control and balance requires cognitive ability in healthy individuals and, more specifically, in geriatric populations. The normal aging process degrades the quality of sensory information, and as a result, the attention demands of maintaining one's posture increases. Taking this, as well as the decreased strength and mobility often associated with aging and lifestyle factors such as decreased activity levels and a fear of falling into consideration, it is important to identify the cause for balance impairments that could result in functional dependence or a fall. A simple assessment of cognition, as it relates to mobility, may provide insight to clinicians. If clinicians have information regarding which functional assessments had the greatest cognitive demands, they could use those assessments to better understand which interventions will have the greatest impact on the outcomes.

CHAPTER III

Methodology

This study was a secondary analysis of cross-sectional data collected during two separate research studies conducted by T. E. Shubert (Ph.D.-M.P.T.), as listed below:

Study 1: Improving Balance through Exercise, UNC-CH IRB: 07-1820 (Appendix A)

Study 2: The Relationship Between Variety of Activity to Physical Function and Balance in Older Adults, UNC-CH IRB: 05-1860 (Appendix B).

Subjects

Potential subjects for *Study 1* were recruited from central North Carolina via word of mouth and advertisements in local newspapers. Subjects for *Study 2* were recruited via flyers and informational sessions offered at senior centers and continuing care retirement facilities in central North Carolina. A total of 450 subjects volunteered for the studies. Of the volunteers, 254 subjects met the screening criteria (detailed below) and 107 subjects had complete data sets and were included in the analyses.

Volunteers were pre-screened during a 15-minute telephone interview. They were accepted into the research study if they were at least 65 years of age at the time of the testing session and did not violate any of the following exclusion criteria either during the pre-screening interview or at the assessment session:

- A known neurological condition;
- A known terminal disease;
- A visual impairment not corrected with corrective lenses;

- Unable to speak, hear, and/or understand English (as determined by the researcher);
and/or
- Unable to follow a three-step command (as determined by the researcher).

Instrumentation

The following instruments were employed in this research study:

Demographic Form (Appendix C). This form, developed by the principal investigator, was used to collect demographic, education level, and medical history information.

Pre-Testing Health Status Screening Questionnaire (Appendix D). This questionnaire, developed by the principal investigator and research team, included screening questions designed to determine if subjects were able to safely perform the physical and cognitive assessments at the time of the testing session.

Procedures

Subjects who met the screening criteria were enrolled in the research study and scheduled for a single testing session. Testing was conducted either at a senior center in central North Carolina (IRB 07-1820) or at a continuing care retirement facility, also in central North Carolina (IRB 05-1860). Upon arrival to the test site, a trained researcher reviewed the *Informed Consent* with the subject and collected the appropriate signatures. The subject completed the *Demographic Form* (Appendix C) and the *Pre-Testing Health Status Screening Questionnaire* (Appendix D), from which the trained researcher confirmed inclusion/exclusion criteria for the study. The researcher also determined whether the subject was able to see, hear and/or understand directions appropriately to be included in the study. The researcher noted any visual or auditory impairment, as well as the inability to speak or

understand English, which would prevent a subject from being able to communicate with researchers and perform physical and cognitive assessments safely and effectively.

The researcher then administered a *Three-Step Command Test*, which required the subjects to perform a series of tasks in the correct sequence. This sequencing task, modeled after the *Luria Three-Step Command Test*, was used to identify the loss of the ability to perform movements, termed apraxia, which is likely caused by damage to the left frontal cortex (Kipps & Hodges, 2005). For these studies, the *Timed Up and Go Test* (TUG) was used as the *Three-Step Command Test*. Per the instructions for the TUG, the following tasks were presented to the subject to perform in this chronological sequence:

1. Stand up from a chair.
2. Walk three meters.
3. Turn around and return to the chair.

Physical and Cognitive Performance Assessments.

All of the following assessments were given in random order. Each assessment was administered by a trained researcher and standardized verbal commands were used to ensure each subject was given the same instructions. Specific verbal instructions are given in the appendix for each assessment. Prior to data collection, trained researchers were assessed for inter- and intra-rater reliability and were only permitted to perform physical assessments if they met or exceeded the reliability published for each validated assessment, as detailed below. All time measurements were recorded to the nearest tenth of a second.

Balance Assessments.

Single-Leg Stance Test (SLS; Appendix E). The SLS required subjects to stand on one leg for as long as possible. The researcher recorded the time until the subject placed the non-

support leg on the ground, reached for support, or until 30.0 seconds had elapsed (Inter- and Intra-rater Reliability: ICC = 0.98; Berg, K. et al., 1989).

Tandem Stance Test (TS; Appendix F). The TS assessment required subjects to stand with a narrow base of support, specifically with one foot directly in front of the other, for as long as possible without becoming unstable/falling, or until 30.0 seconds had elapsed (Inter- and Intra-rater Reliability: ICC = 0.98; Berg, K., et al., 1989).

Four Square Step Test (FSST; Appendix G; Figure 2 on Page 15). The FSST assessed dynamic balance by having individuals step over obstacles through a sequence of squares on the floor (Dite & Temple, 2002); (Inter- and Intra-rater Reliability: ICC = 0.99; Whitney Marchetti, Morris & Sparto, 2007).

Mobility Assessment: 10-Meter Walk Test (10MWT). Gait Velocity was assessed using a 10MWT. During this assessment, subjects self-selected a comfortable pace and walked 10 meters. The 10-meter course included a 2-meter acceleration zone at the beginning of the walkway and a 2-meter deceleration zone at the end of the walkway (Scivoletto et al., 2011). A trained researcher recorded the time that it took the subject to complete the 10-meter walk. Gait Velocity was recorded in meters per second (m/s); (Inter- and Intra-rater Reliability: ICC = 0.95- 0.99; Scivoletto et al., 2011).

Strength Assessment: Timed Chair Rise Test (TCR; Appendix H). The TCR was used to determine muscular strength and endurance. Subjects were instructed to rise from a seated position in a standard-height chair (standardized seat height 43.2 cm from the ground) without the assistance of their arms. The subject's score was recorded as the total time that it took to rise from the chair five times. Subjects were excluded from the analysis if they could

not complete five chair rises; (Inter- and Intra-rater Reliability: ICC = 0.98; Guralnik et al., 2000).

Cognitive Assessment: *Symbol Digit Modalities Test* (SDMT: Appendix I). The SDMT was administered to determine executive function, processing speed, and the ability to switch the focus of one's attention (Smith 1982; Strauss et al., 2006). The score was recorded as the number of correctly paired digits with the given symbols (out of 110) in 90 seconds. An example of the reference pairs and blank assessment were shown in Figure 3 (see Page 18).

Research Design and Statistical Analysis

This study was a secondary analysis of the balance, mobility, strength, and cognitive assessment data collected in the aforementioned research studies. The cross-sectional analysis used physical performance on clinical assessments as predictors for cognitive function as determined by the SDMT.

Descriptive statistics (means, SDs, and percentages of the total sample) were used to describe the population characteristics (age, BMI, sex, medical history, and falls history). Statistical analyses were carried out in SPSS for Windows (Version 19.0). Statistical significance was set a priori at the level of $p \leq 0.05$ for all analyses. In order to test specific research questions, the following statistical analyses were used:

Research Question 1. Does a relationship exist between performance on a cognitive assessment and clinical balance assessments?

RQ 1a: Does a relationship exist between performance on the SDMT and SLS?

Hypothesis 1a: There is no relationship between performance on the SDMT and SLS.

RQ 1b: Does a relationship exist between performance on the SDMT and TS?

Hypothesis 1b: There is no relationship between performance on the SDMT and TS.

RQ 1c: Does a relationship exist between performance on the SDMT and FSST?

Hypothesis 1c: There is a negative relationship between performance on the SDMT and FSST.

Statistical Analyses for RQ1a – RQ 1c.

Balance and Cognitive Function was addressed using a multiple regression analysis (*Model 1*), with each of the clinical balance assessments as a predictor variable for the criterion variable, SDMT. A subsequent analysis (*Model 1a*) was run using a sequential regression in order to control for aging. In *Model 1a*, age was entered into the regression analysis in Block 1, followed by the three balance assessment measures in Block 2.

Research Question 2. Does a relationship exist between performance on a cognitive assessment and clinical mobility assessments?

RQ 2a: Does a relationship exist between performance on the SDMT and Gait Velocity.

Hypothesis 2a: There is a positive relationship between performance on the SDMT and Gait Velocity.

Statistical Analysis for RQ2a.

Mobility and Cognitive Function was addressed using a bivariate linear regression (*Model 2*) with the 10MWT mobility assessment outcome measure (Gait Velocity) as a predictor variable for the criterion variable, SDMT. A subsequent analysis (*Model 2a*) was run using a sequential regression in order to control for aging. In *Model 2a*,

age was entered into the regression analysis in Block 1, followed by the Gait Velocity in Block 2.

Research Question 3. Does a relationship exist between performance on a cognitive assessment and clinical strength assessments?

RQ 3a: Does a relationship exist between performance on the SDMT and TCR?

Hypothesis 3a: A relationship does not exist between performance on the SDMT and TCR.

Statistical Analysis for RQ3a.

Strength and Cognitive Function was addressed using a bivariate linear regression (*Model 3*) with the strength assessment performance measure (TCR) as a predictor variable for the criterion variable, SDMT. *Model 3* was run a second time as a sequential regression (*Model 3a*) in order to control for aging. In *Model 3a*, age was entered into the regression analysis in Block 1, followed by the TCR in Block 2.

Additional analyses.

Independent samples t-tests were run to confirm that there were no sex differences on the physical and cognitive assessments, age and BMI, thereby justifying the combining of the male and female groups into one larger sample and potentially improving the study's statistical power.

CHAPTER IV

Results

Description of Subjects

Subjects for the present analysis volunteered for *Study 1* or *Study 2* between 2006 and 2010 in response to advertisements, word of mouth and/or informational sessions at local senior centers in central North Carolina. The sample for the analyses in this study contained 107 subjects that were at least 65 years old, met all inclusion and exclusion criteria, and had successfully completed all physical and cognitive assessments. Descriptive analyses were run to assess demographics. The sample was predominantly female (74.8%), white (non-Hispanic, 84.0%), and well-educated (82.2% of sample had received post-secondary education). More than half of the sample had not experienced a fall within the 12 months prior to data collection (54.3%) and reported never using an assistive device (78.5%). Characteristics of the subjects in the sample, plus a description of medical conditions and history are given in Table 2 and Table 3 (Pages 29 and 30, respectively).

Independent t-tests were run for age, BMI, and all physical and cognitive assessment variables to determine if there were any differences between sex groups. The results are shown in Table 4 (see Page 30). Men and women did not significantly differ in age or BMI ($p \geq 0.15$) and the mean values for these variables were similar to the overall combined sex data.

Table 2.

Subject Characteristics (n=107).

Variable	Mean \pm SD	Range	% of Sample
Age (years)	78.1 \pm 7.2	65.0 - 93.0	-
BMI (kg/m ²)	25.6 \pm 4.9	16.9 \pm 41.6	-
Sex			
Male	-	-	25.2
Female	-	-	74.8
Ethnicity			
Asian	-	-	4.7
Black	-	-	4.7
White (Hispanic)	-	-	3.7
White (Non-Hispanic)	-	-	84.1
Other	-	-	2.8
Marital Status			
Married	-	-	40.2
Widowed	-	-	39.3
Other	-	-	20.5
Received Post-Secondary Education			
Yes	-	-	82.2
No	-	-	17.8
Visual Impairment			
Yes; Corrected with corrective lenses	-	-	39.3
No	-	-	60.7
History of Fracture			
Yes	-	-	28.0
No	-	-	72.0
Use of Assistive Device			
Never	-	-	78.5
Rarely	-	-	8.4
Some of the time	-	-	9.3
Most of the time	-	-	2.8
All of the time	-	-	0.9
Number of Falls in Previous 12 Months	0.9 \pm 1.1	0 - 6	
0	-	-	54.3%
1	-	-	22.9%
2	-	-	14.3%
≥ 3	-	-	8.7%

Note. Height and weight measurements were not available for four female subjects. BMI was not calculated for these subjects.

Table 3.

Summary of Medical Conditions and History

Medical Conditions	Mean \pm SD	Range	% of Sample
Number of Medical Conditions	2.4 \pm 1.4	0 - 6	-
0	-	-	4.7
1–5	-	-	92.5
6+	-	-	2.8
Arthritis	-	-	60.7
Cancer	-	-	26.2
Diabetes Mellitus (Type 1 and Type 2)	-	-	10.3
Heart Disease	-	-	18.7
Hypertension	-	-	47.7
Neuropathy	-	-	26.2
Osteoporosis	-	-	33.6
Stroke/Neurologic Impairment ^a	-	-	15.0

^a Per the exclusion criteria, trained researchers determined that neurological impairments had no effect on the subjects' ability to participate in the study.

Table 4.

Independent Samples T-Tests Between Sex Groups

Variable	Sex Group	Mean \pm SD	t-score	df	p-value
Age (years)	Male	79.2 \pm 7.2	0.93	105	0.36
	Female	77.7 \pm 7.1			
BMI (kg/m ²)	Male	26.8 \pm 4.9	1.45	101	0.15
	Female	25.2 \pm 4.8			
SDMT (number correct)	Male	39.8 \pm 7.8	0.33	105	0.74
	Female	39.1 \pm 10.3			
SLS (s)	Male	5.2 \pm 4.7	-0.92	105	0.36
	Female	6.6 \pm 7.4			
TS (s)	Male	10.4 \pm 8.9	-2.24	53.5 ^a	0.03*
	Female	15.1 \pm 10.8			
FSST (s)	Male	12.8 \pm 3.8	-0.91	105	0.31
	Female	13.7 \pm 4.8			
Gait Velocity (m/s)	Male	1.1 \pm 0.2	1.54	105	0.13
	Female	1.0 \pm 0.2			
TCR (s)	Male	14.6 \pm 4.5	-0.08	105	0.93
	Female	14.7 \pm 3.6			

Note. Height and weight measurements were not available for four female subjects. BMI was not calculated for these subjects. Note. All timed assessment scores were recorded to the nearest tenth of a second (s). Gait Velocity is the outcome measure of the 10MWT mobility assessment. SLS = Single-Leg Stance Test; TS = Tandem Stance Test; FSST = Four Square Step Test; 10MWT = 10-Meter Walk Test; TCR = Timed Chair Rise; SDMT = Symbol Digit Modalities Test.

^a Levene's Test for Equality of Variances returned a significant difference in the variance between the two sex groups, therefore the df (degrees of freedom) for this balance assessment were adjusted within the SPSS analysis.

*Denotes significance at the $p \leq 0.05$ level.

Physical and Cognitive Performance Assessments

The descriptive analyses on the physical and cognitive variables revealed that the sample was relatively high functioning. Sixty-three percent of the sample walked faster than 1.0 m/s, 52% were able to remain in a tandem-stance position for at least 10 seconds, 76% were able to complete the FSST in less than 15 seconds, and nearly 95% did not display cognitive impairments based on the number of correctly-matched pairs on the SDMT. Mean (\pm SD) assessment scores from the sample, as well as clinical cut-off values for each assessment, are listed in Table 5.

Table 5.

Physical and Cognitive Assessment Scores.

Assessment	Mean ± SD	Range	Clinical Cut-Off ^a	
			Score	% of Sample Scoring Above
Physical Performance				
SLS (s)	6.9 ± 7.9	0.8-30.0	5.0	34.6
TS (s)	13.8 ± 10.7	0.8-30.0	10.0	52.3
FSST (s)	13.2 ± 4.2	6.3-30.7	15.0	75.7
Gait Velocity (m/s)	1.0 ± 0.3	0.5-2.8	1.0	62.6
TCR (s)	14.9 ± 4.7	6.9-36.2	13.6	45.8
Cognitive Performance				
SDMT (# of pairs)	40.0 ± 9.8	13.0-66.0	20.3 ^b	98.1
			26.0 ^c	94.4

Note. All timed assessment scores were recorded to the nearest tenth of a second (s). Gait Velocity is the outcome measure of the 10MWT mobility assessment. SLS = Single-Leg Stance Test; TS = Tandem Stance Test; FSST = Four Square Step Test; 10MWT = 10-Meter Walk Test; TCR = Timed Chair Rise; SDMT = Symbol Digit Modalities Test.

^aClinical Cut-Off Scores represent the point associated with a decline in functionality of the given system. Subjects scoring above the clinical cut-off are at a decreased risk of experiencing functional decline and/or impairment of that system.

^bThe SDMT score of 20.3 is 1.5 SD's below the mean score for adults over the age of 65 years-old with normal cognitive function (Lezak, 2004).

^cThe SDMT score of 26.0 is 1.0 SD's below the mean score for adults over the age of 65 years old with normal cognitive function (Lezak, 2004).

Relationship between Cognitive Function and the Physical Performance Variables

Relationship between cognition and physical performance, unadjusted for age.

Research Question 1 asked: “Does a relationship exist between performance on clinical balance assessments and a cognitive assessment?” To answer this question, a standard multiple linear regression on *Model 1* was employed using the Enter method (in SPSS Version 19.0). This method enters all of the independent variables at one time; they then remain in the model regardless of significance of the resulting correlations. For this analysis, static balance assessments scores (SLS, TS) and the dynamic balance assessment score (FSST) were the independent (predictor) variables and SDMT score was the dependent (criterion) variable.

A summary of the regression analysis for *Model 1*, unadjusted for aging, between the balance assessment scores and the cognitive assessment score is listed in Table 6.

Table 6.

Standard Multiple Regression for Model 1: Balance and Cognitive Function.

	R	R²	df	F	p-value
Model 1 Summary	0.382	0.146	3, 103	5.877	0.001*
Independent variables	Standardized coefficients			Correlations	
	β	Critical t	p-value	Zero-Order	Semipartial
SLS	-0.162	1.607	0.111	0.181	0.146
TS	-0.137	-1.379	0.171	-0.020	-0.126
FSST	-0.331	-3.532	0.001 [#]	-0.345	-0.322

Note. Criterion Variable = SDMT. SLS = Single-Leg Stance Test; TS = Tandem Stance Test; FSST = Four Square Step Test; SDMT = Symbol Digit Modalities Test.

* Denotes a regression model with significance at the $p \leq 0.05$ level.

[#] Denotes a unique contributor (predictor variable) with significance at the $p \leq 0.05$ level.

Model 1, unadjusted for aging, revealed a significant regression model in which nearly 15% of the variance in SDMT score was explained by performance on the balance assessments ($R^2 = 0.146$, $p = 0.001$). As shown in Table 6, only one of the three balance measures (FSST) was a significant unique contributor to the regression ($r_{\text{part}} = -0.322$; $\beta = -0.311$, $p = 0.001$). No other significant findings existed regarding a relationship between cognitive function and the static balance assessment scores.

Due to the fact that the independent samples t-test run on TS times between sex groups revealed that the 27 male subjects and 80 female subjects performed significantly differently on the static balance assessment ($p = 0.03$; Table 4 on Page 29), two separate linear regressions were run for each sex group. The results for these regression analyses revealed that both sex groups had neither a significant bivariate correlation between TS and SDMT, nor a significant regression model predicting cognitive function from TS performance ($p > 0.87$). Table 7 summarizes the male and female regression models.

Table 7.

Standard Linear Regression for TS and Cognitive Function by Sex.

Model Summary	R	R²	df	F	p-value
Sex: Male (n = 27)	0.033	0.001	1, 25	0.027	0.871
	Standardized coefficients			Correlations	
Independent variable	β	Critical t	p-value	Zero-Order	
TS	-0.033	-0.164	0.871	-0.033	
Model Summary	R	R²	df	F	p-value
Sex: Female (n = 80)	0.010	0.000	1, 78	0.008	0.930
	Standardized coefficients			Correlations	
Independent variable	β	Critical t	p-value	Zero-Order	
TS	-0.10	-0.088	0.930	-0.010	

Note. Criterion Variable = SDMT. TS = Tandem Stance Test; SDMT = Symbol Digit Modalities Test.

Research Question 2 asked: “Does a relationship exist between performance on clinical mobility assessments and a cognitive assessment?” To answer this question, a bivariate linear regression, also not adjusted for aging, was used. Gait Velocity, the outcome measure of the 10MWT, was assigned as the independent (predictor) variable and SDMT score was assigned as the dependent (criterion) variable. This mobility regression analysis (*Model 2*), demonstrated that Gait Velocity had a significant positive association with SDMT performance ($r = 0.322$; $p = 0.001$) and also revealed a significant regression model in which the mobility assessment was predictive of cognitive function. ($R^2 = 0.104$, $p = 0.001$). A summary of *Model 2* is displayed in Table 8.

Table 8.

Standard linear regression for Model 2: Mobility and Cognitive Function.

	R	R²	df	F	p-value
Model 2 Summary	0.322	0.104	1, 105	12.128	0.001*
	Standardized coefficients			Correlations	
Independent variables	β	Critical t	p-value	Zero-Order	
Gait Velocity	0.322	3.482	0.001 [#]	0.322	

Note. Criterion Variable = SDMT. Gait Velocity is the outcome measure of the 10MWT mobility assessment. 10MWT = 10-Meter Walk Test; SDMT = Symbol Digit Modalities Test.

* Denotes a regression model with significance at the $p \leq 0.05$ level.

[#] Denotes a unique contributor (predictor variable) with significance at the $p \leq 0.05$ level.

Research Question 3 asked: “Does a relationship exist between performance on clinical strength assessments and a cognitive assessment?” To answer this final question, a bivariate linear regression analysis was run without controlling for age. The score from the TCR assessment was designated as the independent (predictor) variable and the SDMT score was designated as the dependent (criterion) variable. As shown in Table 9, the strength regression

analysis (*Model 3*) revealed that a significant relationship between cognitive function and the clinical strength assessment, TCR did not exist.

Table 9.

Standard Linear Regression for Model 3: Strength and Cognitive Function.

	R	R²	df	F	p-value
Model 3 Summary	0.096	0.009	1, 105	0.973	0.326
Independent variables	Standardized coefficients			Correlations	
	β	Critical t	p-value	Zero-Order	
TCR	-0.096	-0.987	0.326	-0.096	

Note. Criterion Variable = SDMT. TCR = Timed Chair Rise; SDMT = Symbol Digit Modalities Test.

Relationship between cognition and physical performance, adjusted for age.

Due to the known decline in SDMT score with age (Lezak, 2004), each of the regression models were run a second time as sequential multiple regressions controlling for age. For these analyses, age was entered in Block 1, followed by the physical performance measures in Block 2. All independent variables remained in the models regardless of the presence or lack of significant correlations with the criterion variable, SDMT. By removing age as a confounding variable, the unique contribution of each physical performance measure could be assessed within each model. Summaries of the age-adjusted models are given in Tables 10-12 (Pages 35-36).

Table 10.

Model 1a: Age-Adjusted Multiple Regression for Model 1: Balance and Cognitive Function.

		R	R²	df	F	p-value
Model 1a Summary		0.477	0.227	4,102	7.504	<0.0005*
		Standardized coefficients			Correlations	
Independent variables		β	Critical t	p-value	Zero-Order	Semipartial
Block 1	Age	-0.298	-3.274	0.001 [#]	-0.345	-0.285
Block 2	SLS	0.119	1.224	0.224	0.181	0.107
	TS	-0.176	-1.837	0.069	-0.020	-0.160
	FSST	-0.289	-3.191	0.002 [#]	-0.345	-0.278

Note. Criterion Variable = SDMT. SLS = Single-Leg Stance Test; TS = Tandem Stance Test; FSST = Four Square Step Test; SDMT = Symbol Digit Modalities Test.

* Denotes a regression model with significance at the $p \leq 0.05$ level.

[#] Denotes a unique contributor (predictor variable) with significance at the $p \leq 0.05$ level.

Table 11.

Model 2a: Age-Adjusted Multiple Regression for Model 2: Mobility and Cognitive Function.

		R	R²	df	F	p-value
Model 2a Summary		0.427	0.182	2, 104	11.608	<0.0005*
		Standardized coefficients			Correlations	
Independent variables		β	Critical t	p-value	Zero-Order	Semipartial
Block 1	Age	-0.288	-3.169	0.002 [#]	-0.345	-0.281
Block 2	Gait Velocity	0.256	2.849	0.005 [#]	0.322	0.253

Note. Criterion Variable = SDMT. Gait Velocity is the outcome measure of the 10MWT mobility assessment. 10MWT = 10-Meter Walk Test; SDMT = Symbol Digit Modalities Test.

* Denotes a regression model with significance at the $p \leq 0.05$ level.

[#] Denotes a unique contributor (predictor variable) with significance at the $p \leq 0.05$ level.

Table 12.

Model 3a: Age-Adjusted Multiple Regression for Model 3: Strength and Cognitive Function.

		R	R²	df	F	p-value
Model 3a Summary		0.354	0.126	2, 104	7.466	0.001*
		Standardized coefficients			Correlations	
Independent variables		β	Critical t	p-value	Zero-Order	Semipartial
Block 1	Age	-0.341	-3.720	<0.0005 [#]	-0.345	-0.341
Block 2	TCR	-0.083	-0.092	0.369	-0.096	-0.083

Note. Criterion Variable = SDMT. TCR = Timed Chair Rise; SDMT = Symbol Digit Modalities Test.

*Denotes a regression model with significance at the $p \leq 0.05$ level.

[#]Denotes a unique contributor (predictor variable) with significance at the $p \leq 0.05$ level.

Although (age-adjusted) *Models 1a* and *Model 2a* clearly show age to be a significant contributor, uniquely responsible for 29-30% of the predictive models (*Model 1a*: $\beta = -0.298$, $p = 0.001$; *Model 2a*: $\beta = -0.288$, $p = 0.002$), this age-adjusted analyses still retained a significant contribution by FSST from *Model 1* and Gait Velocity from *Model 2*. The unique association between SDMT score and both FSST and Gait Velocity (FSST: $r_{\text{part}} = -0.278$; Gait Velocity: $r_{\text{part}} = 0.253$) contributed 25-28% of *Model 1a* and *Model 2a*, independent of age (FSST: $\beta = -0.289$, $p = 0.002$; Gait Velocity: $\beta = -0.256$, $p = 0.002$). Conversely, while *Model 3a* did return a significant overall correlation coefficient ($R = 0.107$, $p = 0.003$), the semipartial correlations indicate that the only variable contributing to the significant regression model was age ($r_{\text{part}} = -0.341$, $\beta = -0.341$, $p < 0.0005$).

The age-adjusted regression analyses returned a model predicting cognitive function from TS score in the female group that was dissimilar to that of the male group. The regression models are summarized in Table 13 (Page 38).

Table 13.

Age-Adjusted Multiple Regressions for TS and Cognitive Function by Sex.

Model Summary		R	R ²	df	F	p-value
Sex: Male (n = 27)		0.180	0.032	2, 24	0.400	0.675
		Standardized coefficients			Correlations	
Independent variable		β	Critical t	p-value	Zero-Order	Semipartial
Block 1	Age	-0.197	-0.880	0.388	-0.143	-0.177
Block 2	TS	-0.121	-0.539	0.595	-0.033	-0.108
Model Summary		R	R ²	df	F	p-value
Sex: Female (n = 80)		0.409	0.167	2, 77	7.713	0.001*
		Standardized coefficients			Correlations	
Independent variable		β	Critical t	p-value	Zero-Order	Semipartial
Block 1	Age	-0.412	-3.962	<0.0005 [#]	-0.404	-0.408
Block 2	TS	-0.063	-0.598	0.552	-0.010	-0.062

Note. Criterion Variable = SDMT. TS = Tandem Stance Test; SDMT = Symbol Digit Modalities Test.

* Denotes a regression model with significance at the $p \leq 0.05$ level.

[#] Denotes a unique contributor (predictor variable) with significance at the $p \leq 0.05$ level.

The female group revealed a significant, age-adjusted regression model accounting for nearly 17% of the variability in SDMT performance ($p = 0.001$). The only significant contributor to the model was age ($r_{\text{part}} = -0.408$, $\beta = -0.412$, $p < 0.0005$), which is similar to the findings from other age-adjusted regression models within this study. The male group, however, lacked any significant results for the age-adjusted model ($R = 0.180$, $p = 0.675$). Neither age nor TS were significantly associated with SDMT performance in this sex group ($p = 0.388$ and $p = 0.595$ for age and TS, respectively).

CHAPTER V

Discussion

Predictors of Cognitive Assessment Performance

In the clinical setting, cognitive assessments are infrequently administered as a part of comprehensive balance assessment, despite the known relationship between cognitive function and postural control. Determining the relationship between functional physical assessments and cognition and, more specifically, the predictive value that these physical assessments have, will provide clinicians with information regarding what component of postural control is lacking and leading to fall risk. The results of the present analyses suggest that the FSST score and Gait Velocity are each independent, significant predictors of SDMT, a cognitive function assessment.

Within the *Balance and Cognitive Function* models (*Model 1* and *Model 1a*), the bivariate and semipartial coefficients of correlation for the FSST suggest that of the balance assessments used in the present analyses, FSST significantly contributes to SDMT score while SLS and TS do not. When age is not taken into consideration (*Model 1*), the coefficient of determination reveals that the overall balance model, including FSST, SLS and TS, is a weak, yet significant predictor of cognitive function. *Model 1* explains nearly 15% of the variability in SDMT score, with nearly twice the contribution from FSST alone than from either SLS or TS. Interestingly, when adjusted for age (*Model 1a*), while the overall predictive ability of the models improves tremendously, the independent predictive ability of

FSST nearly matches that of age (28% vs. 29%, respectively). Therefore, FSST is truly an important predictor of cognitive function.

The negative relationship between FSST and SDMT is expected, given the fact that the goal of the FSST is to achieve a faster (or lower) time and the goal of the SDMT is to correctly match as many digits with symbols as possible (higher) in a given amount of time. The FSST was designed to be able to identify fall risk in those individuals who have less pronounced or severe balance impairments (Dite & Temple, 2002). Stepping and maneuvering through the course requires skill, focus and coordination.

Model 1 and *Model 1a* reveal that no static balance assessment was significantly associated with cognitive function. However, in the age-adjusted *Balance and Cognitive Function* model, TS did trend toward a significant negative relationship with SDMT score in the bivariate analysis ($r_{\text{part}} = -0.160$, $p = 0.069$). Therefore, TS improved the age-adjusted regression model when paired with FSST and independently accounted for 16% of the variance in the overall model ($R^2 = 0.227$, $p < 0.0005$).

Model 2 confirms the relationship between walking velocity and cognitive function previously reported by Holtzer et al. (2006). Both *Model 2* and *Model 2a* suggest a significant relationship between SDMT score and Gait Velocity with and without controlling for aging. Similar to the findings with FSST, the independent predictive ability of Gait Velocity nearly matched that of age (25% and 28%, respectively). Holtzer et al. (2006) also revealed that a neuropsychological battery assessing several cognitive function domains, including processing speed and executive function, was a significant predictor for Gait Velocity ($p < 0.0005$). They concluded that processing speed and executive function provided the greatest contribution to the predictive model for gait speed (Holtzer et al.,

2006). Unfortunately, due to the reversal of independent and dependent variables, more specific comparisons between their analyses and those in this study are not possible.

Strength and Cognitive Function (Model 3) did not reveal a significant relationship between TCR and SDMT independent from age. Therefore, the significant regression resulting from the age-adjusted *Strength and Cognitive Function* model (*Model 3a*) indicates that aging alone has a strong, unique impact on the relationship between TCR and SDMT. In the present study, lower body strength was assessed simply via the ability to rise from a chair without the use of one's arms. However, due to the fact that the maneuver is repeated several times consecutively, this functional assessment also has an endurance component. Therefore, within *Model 3* and *Model 3a*, endurance was a potential confounding factor due to the known negative relationship between muscular endurance and aging (Spirduso, Francis & MacRae, 2004). Furthermore, Lord et al. (2002) showed that TCR score is also related to proprioception, visual sensitivity, tactile sensitivity, simple reaction time, static standing balance, reported levels of anxiety, vitality and pain (Lord et al., 2002).

Limitations

The sample of older adults used in the present study was very well-educated when compared to national averages and performed above the age-group's expected norms on the cognitive assessment. The 82% of subjects had received post-secondary education in this study, which is well above the national (20%) or state (18.4%) averages (Administration on Aging, 2012; U. S. Census Bureau, 2011). The SDMT age norm of 37.4 (± 11.4) for adults 65-74 years old is below the mean score of 40 (± 10) attained by the current subject sample, despite the fact that the group in this study had a mean age that was older than the reference age range and SMDT score trends downward with age (Lezak, 2004; Smith, 1982). Based on

the clinical determinants of cognitive dysfunction published by Smith (1982), only 4.7% of the sample falls in the “suggestive of cognitive impairment” category and 1.1% of the sample falls into the “indicative of cognitive impairment” category. According to 2011 U. S. Census data, 10.9% of adults over 65 years old in North Carolina have cognitive difficulty (UNC Institute on Aging, 2008; 2011).

Due to the fact that the sample performed above average on the cognitive assessment, but displayed some functional impairment on the physical assessments, the strength of the relationships analyzed in this study may have been confounded. It appears that the more demanding balance and mobility assessments are still related to cognitive function, despite the education status and SDMT performance in this sample.

Additionally, while information was collected regarding medical conditions and history, no measures were taken to account for specific diseased populations. Many medical conditions can affect cognitive function, physical function and/or balance, and the presence of these conditions could have affected the relationship between cognitive assessment performance and balance, mobility and/or strength assessment performance in this study.

CHAPTER VI

Summary and Conclusions

Summary

The purpose of this study was to contribute additional information to the existing falls prevention literature by investigating the relationship between cognitive function and functional performance (balance, mobility and strength) in elderly volunteers. Subjects used in these analyses were recruited from central North Carolina for one of two separate research studies completed between 2006 and 2010. From the total sample, 107 older adults (74.8% female) between the ages of 65 and 93 (mean 78.1 ± 7.2) were used for the analyses within this study. All of the subjects had completed at least 12 years of school, with 82.2% of the sample receiving post-secondary education. None of the subjects had a(n) (1) known neurological condition; (2) terminal disease; (3) uncorrected visual impairment; (4) inability to speak, hear and/or understand English; and/or (5) inability to follow a three-step command.

This study demonstrated a significant relationship between both clinical balance and mobility assessment scores and cognitive function. Specifically, the FSST, a dynamic balance assessment, and Gait Velocity (determined by the 10MWT) were significant predictors of SDMT score. Controlling for age did not significantly reduce the strength of the relationship between SDMT and either FSST score or Gait Velocity. Conversely, age was the predominant contributor to the *Strength and Cognitive Function* model.

Conclusions

Research Question 1: Does a relationship exist between performance on clinical balance assessments and a cognitive assessment?

Research Question 1a: Does a relationship exist between performance on the SDMT and SLS?

Hypothesis 1a: There is no relationship between performance on the SDMT and SLS.

The null hypothesis that there is no relationship between SDMT and SLS score is not rejected, due to the lack of a significant correlation between SLS and SDMT.

Therefore, *Hypothesis 1a is accepted.*

Research Question 1b: Does a relationship exist between performance on the SDMT and TS?

Hypothesis 1b: There is no relationship between performance on the SDMT and TS.

Similar to findings between SDMT and SLS, the null hypothesis for *RQ1b* that there is no relationship between SDMT and TS score is not rejected. There was not a significant correlation between TS and SDMT in this study. Therefore,

Hypothesis 1b is accepted.

Research Question 1c: Does a relationship exist between performance on the SDMT and FSST?

Hypothesis 1c: There is a negative relationship between performance on the SDMT and FSST.

The null hypothesis that there is no relationship between SDMT and FSST score is rejected, due to the significant correlation between SLS and FSST with and without an adjustment for age. Therefore, Hypothesis 1c is accepted.

Research Question 2: Does a relationship exist between performance on clinical mobility assessments and a cognitive assessment?

Research Question 2a: Does a relationship exist between performance on the SDMT and Gait Velocity.

Hypothesis 2a: A positive relationship exists between performance on the SDMT and Gait Velocity.

The null hypothesis that there is no relationship between SDMT and Gait Velocity is rejected, due to the significant correlation between Gait Velocity and SDMT.

This statistically significant correlation between Gait Velocity and cognitive function was evident in *Model 2* and *Model 2a*, indicating that Gait Velocity is a significant, yet weak predictor of SDMT score even when controlled for age.

Therefore, Hypothesis 2a is accepted.

Research Question 3: Does a relationship exist between performance on clinical strength assessments and a cognitive assessment?

Research Question 3a: Does a relationship exist between performance on the SDMT and TCR?

Hypothesis 3a: There is no relationship between performance on the SDMT and TCR.

The null hypothesis that there is no relationship between SDMT and TCR score is not rejected, due to the lack of a significant correlation between TCR and SDMT.

The same results were evident in the regression models that were adjusted and also unadjusted for age. Therefore, *Hypothesis 3a is accepted.*

Clinical Applications

The moderate strength of the balance and mobility regression models are significant in that they provide new insight into the relationship between the two types of physical assessments and cognitive function. Based on the recommendations by the AGS and BGS, it is important to evaluate balance itself, as well as the many factors that influence it (PPFOP et al., 2011). Cognitive function has been identified as a risk factor for experiencing a fall and decreased functionality in elderly individuals (PPFOP et al., 2011; Tinetti et al., 1988). The amount and quality of sensory information available declines with age, therefore seemingly simple tasks such as walking or talking while walking are more cognitively demanding for an elderly person (Brauer, Woollacott & Shumway-Cook, 2001; Sparrow, Bradshaw, Lamoureaux & Tirosh, 2002). For an individual experiencing cognitive deficits due to injury or disease, the cognitive demand of walking could result in a fall (Tinetti et al., 1988).

For community-dwelling older adults, balance exercise interventions appear to be the most effective at preventing a fall (Gillespie et al., 2010). Balance exercises that are challenging, incorporate a narrow base of support (e.g. standing on one leg), and require minimal upper extremity support appear the most effective (Sherrington, Lord & Finch, 2004). Balance interventions that include cognitive challenges, such as dual-tasking, also appear to be effective at decreasing fall risk (Shumway-Cook & Woollacott, 2000). Training static and dynamic balance, strength, and mobility are incorporated into these types of protocols.

It appears that those with higher cognition reap different benefits from balance programs than those with low cognitive performance (Jensen et al., 2003; Shubert, 2010). A review of the effectiveness of physical interventions on balance and mobility in individuals with cognitive deficiencies reported that training programs were often multi-factorial and incorporated some aspect of gait training (Hauer, Becker, Lindemann & Beyer, 2006a). However, none of the studies reviewed by Hauer et al. (2006a) reported significant positive outcomes of physical training in these populations and the researchers concluded that this area is “clearly understudied”. While not included in the aforementioned review, Jensen et al. (2003) reported that when dealing with cognitively-deficient individuals, physical training had little to no effect on balance and postural control, and therefore, does not effectively reduce fall risk.

Falls prevention guidelines highlight the fact that identifying a risk factor without directly addressing and training that particular component of postural control could result in an ineffective intervention (PPFOP et al., 2011). Vellas et al. (1998) contend that balance training is the more critical feature in risk reduction. Their rationale is that balance and mobility training have greater impacts on an individual’s perception of their own balance. Furthermore, the choice of the particular training regimen does have an influence on the amount of benefit that could result (PPFOP et al., 2011). This appears to be more true when dealing with cognitively-deficient older adults. Therefore, clinicians need to assess all of the pieces that are incorporated into balance ability and postural control, including cognitive function, in order to appropriately determine cause for functional decline and fall risk.

Clinicians should incorporate the balance and mobility assessments noted in this study, specifically the FSST and 10MWT (or a similar assessment that reveals Gait Velocity) into

comprehensive balance and fall risk assessment protocols as a way to gain insight to the cognitive function of patients. Individuals identified with cognitive dysfunction should receive interventions that include cognitive training, as well as the physical training normally prescribed to older adults with a risk for falling. Interventions may also be restructured in order to maximize the patients' specific cognitive abilities. While the specific types of interventions that are most effective for these populations have yet to be identified, dual-tasking and reaction time drills during static and dynamic exercises are being employed in physical therapy settings (Hauer et al., 2006a).

Recommendations for Future Research

In light of demonstrating a significant relationship between cognitive function and balance/mobility assessments, future research should be directed toward determining what type of balance and mobility training programs are best suited for those with cognitive dysfunction. In a longitudinal clinical trial, participants with cognitive impairments should receive either traditional balance training (control) or an intervention that incorporates cognitive challenge tasks into the training. It will also be important to determine the frequency, duration, and schedule of practice (blocked or variable) that is most appropriate for individuals with cognitive impairments.

Future studies should take the possible presence of confounding variables into consideration. In geriatric samples, factors such as body composition, aerobic fitness level, and muscular strength/endurance could act as confounding variables on any of the physical performance measures. Similarly, the presence of a history of various medical conditions could have a similar effect on this relationship. Therefore, these variables should be accounted for in future studies.

Appendix A

To: Tiffany Shubert
Aging Program, Division of Geriatrics
104 MacNider, CB 7550,
Chapel Hill, NC 27599-7550, USA

From: Office of Human Research Ethics

Date: 3/16/2012

RE: Determination that Research or Research-Like Activity does not require IRB Approval
Study #: 12-0493

Study Title: A secondary analysis of a balance exercise program for older adults
This submission was reviewed by the Office of Human Research Ethics, which has determined that this submission does not constitute human subjects research as defined under federal regulations [45 CFR 46.102 (d or f) and 21 CFR 56.102(c)(e)(I)] and does not require IRB approval.

Study Description:

Purpose: This study will review data collected from 2007 - 2010 from older adults participating in a balance class that was previously approved by the IRB committee to determine cross-sectional and longitudinal relationships between physical and cognitive function and the impact of a balance program.

Participants: Participants were adults aged 65 and older who participated in a balance class offered at senior centers twice a week for 24 weeks.

Procedures (methods): This will be a secondary analysis of the data collected from IRB #07-1820. During 2007 - 2010, approximately 200 individuals participated in a balance intervention study that required a baseline measurement of demographics, physical and cognitive performance measures, they then participated in a 12-week balance exercise program, and completed a 12-week assessment, and for those who volunteered, they could continue the program for 12 more weeks and then complete a 24-week final assessment. The data to be analyzed for this project was previously collected under the protocols and procedures for that study. The procedures for this study will include reviewing the data set, cleaning the data set, and running statistical analyses on the data to determine relationships between balance, strength and cognition.

If your study protocol changes in such a way that this determination will no longer apply, you should contact the above IRB before making the changes.

Appendix B

2/23/12

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Human Research :

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Print

Study Information

Relationships Between Variety of Activity to Functional Outcomes and Balance in Older Adults

IRB ID: 05-1860
P.I.: Tiffany Shubert
Department: Institute On Aging
Sponsor: Institute on Aging
State:: Approved
IRB : Non-Biomedical
Approval Date : April 12, 2011
Expiration Date : April 10, 2012

» Modifications & Renewals :

Submission Type	Submitted	State	Approved	Review Type
Modification	05/23/2011	Not Approved		Expedited
Renewal	04/12/2011	Approved	04/12/2011	Expedited
Renewal	04/22/2010	Approved	04/22/2010	Expedited
Renewal	05/08/2009	Approved	05/11/2009	Expedited
Renewal	05/14/2008	Approved	05/27/2008	Full Board
Modification	08/29/2007	Approved	09/06/2007	Expedited
Renewal	05/09/2007	Approved	06/11/2007	Full Board
Renewal	05/04/2006	Approved	05/22/2006	Full Board
Modification	11/01/2005	Approved	11/02/2005	Expedited
Modification	08/15/2005	Approved	08/23/2005	Expedited

» Adverse Events :

Submitted	State	Approved	Review Type
There are no adverse events for this application			

» Description :

Aging is often associated with a decrease in the variety and variability of daily routines. This lack of variety of activity could be a contributing factor to declines in mobility, balance, and attention often seen in older adults. This study is testing a questionnaire developed to measure the activities participated by adults age 70 and older in multiple areas (social, cognitive, physical activity, exercise). Information from this tool will be used to determine if adults who participate in a greater variety of

https://apps.research.unc.edu/my_research/human_research_detail.cfm?key=37890

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2/23/12

Research at Carolina » Technology: Report Window

activities during an average week perform better on assessments of walking, strength, balance and attention.

Close

Appendix C

DEMOGRAPHIC FORM

Adapted from form used in:

Study 1, UNC-CH IRB: 01-1820 and *Study 2*, UNC-CH IRB: 05-1860

Subject Number _____

Gender: _____ Male _____ Female

Height _____ inches Weight _____ lbs

What is your race/ethnicity:

A. Black	D. White (Hispanic)
B. Asian	E. Other
C. White (non-Hispanic)	

Are you currently: (select one)

- _____ Married
_____ Widowed
_____ Divorced/Separated
_____ Never married
_____ Other: Specify _____

When did you finish school? (select one)

- _____ Before high school
_____ High School
_____ Associate of Arts degree
_____ Bachelor's degree
_____ Graduate Degree

During the past six months, how many days were you so sick that you could not do usual activities, housework, etc.?

_____ days.

Any sick days during the past two weeks? _____ days

Do you have any of the following conditions?

_____ Heart Disease

_____ Arthritis

_____ High Blood Pressure

_____ Osteoporosis

_____ Cancer

_____ Fracture

Type _____

Where? _____

When? _____

_____ Diabetes
(high sugar)

_____ Problems with Vision

_____ Neuropathy
(numbness in hands or feet)

_____ Stroke

When? _____

Which side? _____

How often do you use an assistive device such as a cane or walker?

___ All of the time

___ Most of the time

___ Some of the time

___ Rarely

___ Never

How many times in the past year did you fall? _____ times

Where did you fall? _____

How did you fall? _____

When did you fall? _____

How many of those falls resulted in injuries? _____

Appendix D

PRE-TESTING HEALTH STATUS SCREENING QUESTIONNAIRE

Adapted from questionnaire used in:

Study 1, UNC-CH IRB: 01-1820 and *Study 2*, UNC-CH IRB: 05-1860

Do you have ANY pain today? If YES, where?

Have you had any signs of problems with your blood pressure today (such as dizziness or headache)?

Have you had any signs of problems with your blood sugar today?

Have you had ANY surgical or medical procedures in the past 6 months?
If yes, what type?

Do you have any concerns that you may not be able to participate in the testing today?

Uncorrected visual impairment?	Y	N
--------------------------------	---	---

Read, hear and understand English?	Y	N
------------------------------------	---	---

Able to follow a three-step command?	Y	N
--------------------------------------	---	---

Appendix E

SINGLE-LEG STANCE TEST (SLS) PROTOCOL

Description:

Balance ability during a Single-Leg Stance.

Adapted from “Measuring Balance in the elderly: Validation of an instrument” by K. Berg, 1992, Canadian Journal of Public Health 83: S7-S11.

Instructions:

Verbal Instruction:

This test helps us to assess your standing balance. I want you to stand on one leg as long as you can without holding on. Watch while I demonstrate.

(Demonstrate using chair/table for initial support.)

You may choose either foot to stand on. You must keep the leg that is off the ground away from the standing leg. You may not brace the free leg on the standing leg. You may use your arms, bend your knees, or move your body to maintain your balance, but try not to move your feet. Hold this position until I say “stop.”

Do you have any questions?

When you are ready, pick up one of your feet from the floor and hold it as long as you can.

Use a stop-watch to time the performance and watch closely for balance problems. Start timing when hand leaves the chair/table. Stop timing when their free foot touches the ground, their hand contacts the chair/table, or 30 seconds has passed.

Make sure you are close enough to guard the subject and that the subject understands they should put their foot down before they fall.

Record the time to a tenth of a second.

Appendix F

TANDEM STANCE TEST (TS) PROTOCOL

Description:

Assessment of static balance.

Adapted from “Measuring Balance in the elderly: Validation of an instrument” by K. Berg, 1992, Canadian Journal of Public Health 83: S7-S11.

Instructions:

Residents should wear tennis shoes or shoes with low or no heels. Describe the motion to the resident as you demonstrate it. Stress that if the resident feels it would be unsafe to try, he/she should not attempt to do it. Emphasize this without alarming the resident. If the activity is not being done properly, demonstrate it again or repeat instructions. Guard the resident for balance loss.

Verbal Instruction:

This test will help us assess your balance during standing. First I will show you the position and then I want you to try it.

(Demonstrate the position.)

Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. After I say start, you will stay in this position for 10 seconds. You may use your arms, bend your knees, or move your body to maintain your balance, but try not to move your feet. Hold this position until I say “stop.”

If you cannot do the position, or you feel it would be unsafe, tell me. Let me emphasize that I do not want you to try any exercise you feel might be unsafe.

Do you have any questions before we begin?

Stand next to the subject to help him/her into the position. Make sure you have a table or chair the subject can use for support. Supply just enough support to the resident's arm to prevent loss of balance. As soon as the resident has his/her feet in position, ask the participant if he/she is ready.

After the subject is in position, let go and say “start” and begin timing. Stop after 10 seconds, or when the subject steps out of position.

Record the time held to the nearest tenth second.

Appendix G

FOUR SQUARE STEP TEST (FSST) PROTOCOL

Description:

A higher order task assessing dynamic balance.

Adapted from “A clinical test of stepping and change of direction to identify multiple falling older adults” by W. Dite and V. A. Temple, 2002, Archives Physical Medicine and Rehabilitation, 83, 1566-1571.

Instructions:

Place two canes on the ground to form four squares (See Figure 2 on Page 15).

Participants start in square one facing square two. Participants step forward into square two, sideways to square three, backwards to square four, sideways into one, and then reverse the sequence - sideways into four, forward, sideways, and backwards.

Instructions are to complete the sequence as fast as possible without touching the canes, both feet must make contact with the floor in each square, and to try to stay facing forward during the entire sequence.

Participants should wear their usual shoes and are allowed to turn their body to negotiate the canes if necessary.

Miss-trials occur if the subject cannot complete the sequence, lose balance or steps on a cane. One miss-trial will be allowed.

Special Instructions: Subjects may lose balance - Make sure you are guarding. You can cue the subjects through the practice, but they should do the subsequent trials without cueing. The most common error is not reversing the sequence at box four.

Verbal Instruction:

We are going to do a stepping test to check your balance. This is what I want you to do: (Demonstrate sequence and verbalize sequence while you are demonstrating.)

Now I want you to practice.

The participant is allowed one practice and two timed trials.

Use a stop-watch to time the performance and watch closely for balance problems.

Start timing from the word “go” and stop timing when both feet are on the ground in square one (after completing the reverse sequence).

Record the time it takes to complete the task to the nearest tenth of a second.

Appendix H

TIMED CHAIR RISE TEST (TCR) PROTOCOL

Description:

Measures the ability of person to rise from a chair. It is a complex test requiring lower limb strength, range of motion, balance, and endurance.

Adapted from “A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission” by J. M. Guralnik et al., 1994, Journal of Gerontology. 49: M85-94.

Instructions:

*Standard-Height Chair = Seat height is 42.3 cm (17.0 inches) from the ground

Single Chair Rise

Have the subject sit erect in a standard-height chair with the chair back against the wall.

Ask the subject to fold both arms across his or her chest.

Instruct the subject to stand up one time without using arms.

Record whether or not he was able to do this.

If the subject was NOT able to get up with arms folded, stop testing at this point.

If the subject was successful with the Single Chair Rise, continue to the Repeated Chair Rise.

Repeated Chair Rise

Have the subject sit erect in a standard-height chair with the chair back against the wall.

Ask the subject to fold both arms across his or her chest.

Instruct the subject to stand up one time without using arms.

Verbal Instructions:

When I say go, I want you to stand up and sit down as quickly as you can five times in a row.

Record the time from the command “go” until the subject is in the final standing position.

Record number of completed chair rises.

Appendix I

SYMBOL DIGIT MODALITIES TEST (SDMT) PROTOCOL

Adapted from “Symbol Digit Modalities Test (SDMT): manual (revised)” by A. L. Smith, 1982.

1. Place the laminated sheet in front of the subject. Use a blank piece of paper to cover up all but the first two rows. You may want to say that this is a matching game.
2. “In this task, you will use this key (point), to complete the page of symbols. Please look at the key at the top of the page. You can see that each box in the upper row has a mark in it. Now look at the boxes in the row just underneath the marks. Each of the boxes under the marks has a number. Each of the marks in the top row is different, and under each mark in the bottom row is a different number.”
3. Then say “Now look at the rest of the sheet. Notice that the boxes on the top have marks, but the boxes underneath are empty. I want you to tell me which number matches the mark and should go in the empty box underneath the mark. Use the key at the top of the page as a guide.”
4. Start the sample items by saying “For example if you look at the first mark, and then look up at the key, you will see that the number 1 goes in the first empty box. So write the number 1 in the first box and so on.”
5. Make a vertical line to indicate the end of the sample and the start of the test.
6. Then say “The boxes here are just practice, why don’t you try it.”
7. Once the participant finishes the practice set, say “Now you will have 90 seconds to match as many boxes as you can on the rest of the sheet. In other words, when you come to the end of the first line, go quickly to the next line without stopping and so on. If you make a mistake, you can tell me the correct answer. Do not skip any boxes and work as quickly as you can. Start when you are ready.”
8. Start the stopwatch at the first number is being drawn.
9. Stop the participant after 90 seconds (1 minute, 30 seconds).
10. Use the answer key to record any mistakes and to mark how far the subject progressed.

See Table 1 for normative scores.

See Figure 3 for sample symbol-digit reference pairs and blank assessment.

Record the score as the total number of correctly matched pairs completed within 90 seconds

REFERENCES

- Administration on Aging. (2012). A Profile of Older Americans: 2011. Retrieved from: http://www.aoa.gov/AoARoot/Aging_Statistics/Profile/2011/16.aspx. (Last accessed on June 14, 2012).
- Berg, K. (1989). Balance and its measure in the elderly: a review. *Physiother Can*, 41(5), 240-246.
- Berg, K. (1992). Measuring balance in the elderly: validation of an instrument. *Can J Public Health*, 83, S7-S11.
- Berg, K., Wood-Dauphinee, S., Williams, J. O., & Gayton, D. (1989). Measuring balance in the elderly preliminary development of an instrument. *Physiother Can*, 41(6), 304-311.
- Berg, W. P., Alessio, H. M., Mills, E. M., & Tong, C. (1997). Circumstances and consequences of falls in independent community dwelling older adults. *Age Ageing* 26, 261-268.
- Black, F. O., Wall, C., & Nasher, L. M. (1983). Effects of visual and support surface orientation references upon postural control in vestibular deficient subject. *Acta Otolaryngol*, 95, 199-210.
- Brauer, S. G., Woollacott, M., & Shumway-Cook, A. (2001). The interacting effects of cognitive demand and recovery of postural stability in balance-impaired elderly persons. *J Gerontol Med Sci*, 56A(8), M489-M496.
- Buchner, D. M., Cress, M. E., Wagner, E. H., de Lateur, B. J., Price, R., & Abrass, I. B. (1993). The Seattle FICSIT/MoveIt study: the effect of exercise on gait and balance in older adults. *J Am Geriatr Soc*, 4(3), 321-325.
- Cumming, R.G., & Klineberg, R.J. (1994). Fall frequency and characteristics and the risk of hip fractures. *J Am Geriatr Soc*, 42, 774-778.
- Dite, W., & Temple, V. A. (2002). A clinical test of stepping and change of direction to identify multiple falling older adults. *Arch Phys Med Rehabil*, 83, 1566-1571.
- Gill, T. M., Williams, S. C., deLeon, C. F. M., & Tinetti, M. E. (1997). The role of change in physical performance in determining risk for dependence in activities of daily living among nondisabled community-living elderly persons. *J Clin Epidemiol*, 50, 765-772. doi:10.1016/S0895-4356(97)00065-6
- Gill, T. M., Williams, C. S., Richardson, E. D., & Tinetti, M. E. (1996). Impairments in physical performance and cognitive status as predisposing factors for functional dependence among nondisabled older persons. *J Gerontol A Biol Sci Med Sci*, 51, M283-M288.

- Gill, T. M., Williams, C. S., & Tinetti, M. E. (1995). Assessing risk for the onset of functional dependence among older adults: the role of physical performance. *J Am Geriatr Soc*, 43, 603-609.
- Gillespie, L. D., Robertson, M. C., Gillespie, W. J., Lamb, S.E., Gates, S., Cumming, R. G., Rowe, B.H. (2010). Interventions for preventing falls in older people living in the community. *Cochrane Database Syst Rev*, 2, CD007146. doi: 10.1002/14651858.CD007146.pub2
- Guccione, A. A., Wong, R. A., & Avers, D. (2011). *Geriatric Physical Therapy (3rd ed.)*. St. Louis, MO: Elsevier Mosby.
- Guralnik, J. M., Ferrucci, L., Pieper, C. F., Leveille, S. G., Markides, K. S., Ostir, G. V.,... Wallace, R. B. (2000). Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. *J Gerontol A Biol Sci Med Sci*, 55, M221-231. doi: 10.1093/gerona/55.4.M221
- Guralnik, J. M., Simonsick, E. M., Ferrucci, L., Glynn, R. J., Berkman, L. F., Blazer, D. G.,... Wallace, R. B. (1994). A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol*, 49, M85-94. doi:10.1093/geronj/49.2.M85
- Hauer, K., Becker, C., Lindemann, U., & Beyer, N. (2006a). Effectiveness of physical training on motor performance and fall prevention in cognitively impaired older persons: a systematic review. *Am J Phys Med Rehabil*, 85(10), 847-857. doi: 10.1097/01.phm.0000228539.99682.32
- Hauer, K., Lamb, S. E., Jorstad, E. C., Todd, C., & Becker, C. (2006b). Systematic review of definitions and methods of measuring falls in randomised controlled falls prevention trials. *Age Ageing*, 35, 5-10. doi:10.1093/ageing/afi218
- Hausdorff, J. M., Rios, D. A., & Edelberg, H. K. (2001). Gait variability and fall risk in community-living older adults: a 1-year prospective study. *Arch Phys Med Rehab*, 82(8), 1050-1056.
- Hill, K., Schwartz, J., Flicker, L., & Carroll, S. (1999). Falls among healthy, community-dwelling, older women: a prospective study of frequency, circumstances, consequences and prediction accuracy. *Aust N Z J Public Health*, 23, 41-48.
- Holtzer, R., Friedman, R., Lipton, R. B., Katz, M., Xue, X., & Verghese, J. (2007). The relationship between specific cognitive functions and falls in aging. *Neuropsych*, 21(5), 540-548. doi:10.1037/0894-4105.21.5.540
- Holtzer, R., Verghese, J., Xue, X., & Lipton, R. B. (2006). Cognitive processes related to gait velocity: results from the Einstein Aging Study. *Neuropsych*, 20(2), 215-223.

- Jack, C. I. A., Smith T., Neoh C., Lye M., & McGalliard J. N. (1995). Prevalence of low vision in elderly patients admitted to an acute geriatric unit in Liverpool: elderly people who fall are more likely to have low vision. *Gerontol*, 41, 280–285. doi: 10.1159/000213695
- Jensen, J., Nyberg, L., Gustafson, Y., & Lundin-Olsson, L. (2003). Fall and injury prevention in residential care-effects in residents with higher and lower levels of cognition. *J Am Geriatr Soc*, 51, 627-635.
- Kipps, C. M., & Hodges, J. R. (2005). Cognitive Assessments for Clinicians. *J Neurol Neurosurg Psychiatry*, 76(Suppl I), i22-i30.
- Lezak, M. D. (2004). *Neuropsychological Assessment* (4th ed.). New York, NY: Oxford University Press.
- Lord, S. R., Clark, R. D., & Webster, I. W. (1991). Postural stability and associated physiological factors in a population of aged persons. *J Gerontol*, 46, M69-76. doi: 10.1093/geronj/46.3.M69
- Lord, S. R., Lloyd, D. G., & Li, S. K. (1996). Sensori-motor function, gait patterns and falls in community-dwelling women. *Age Ageing*, 25, 292-299. doi:10.1093/ageing/25.4.292
- Lord, S. R., Murray, S. M., Chapman, K., Munro, B., & Tiedemann, A. (2002). Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people. *J Gerontol A Biol Sci Med Sci*, 57, M539-543. doi: 10.1093/gerona/57.8.M539
- Lord, S. R., & Sturnieks, D. L. (2005). The physiology of falling: assessment and prevention strategies for older people. *J Sci Med Sport*, 8(1), 35-42.
- McVey, L. J., & Studenski, S. A. (1988). Falls in the Elderly. *Adv Clin Rehabil*, 1, 108-131.
- Panel on Prevention of Falls in Older Persons (PPFOP), American Geriatrics Society (AGS), & British Geriatrics Society (BGS) (2011). Summary of the updated AGS/BGS Clinical Practice Guideline for Prevention of Falls in Older Persons developed by the Panel on Prevention of Falls in Older Persons. *J Am Geriatr Soc*, 59(1), 148-157. doi: 10.1111/j.1532-5415.2010.03234.x
- Podsiadlo, D., & Richardson, S. (1991). The timed “Up & Go”: a test of basic functional mobility for fail elderly persons. *J Am Geriatr Soc*, 39(2): 142-148.
- Pollock, A. S., Durward, B. R., & Rowe, P. J. (2000). What is balance? *Clin Rehabil*, 14(4), 402-406.
- Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychol Rev*, 103(3), 403-428. doi:10.1037/0033-295X.103.3.403

- Scivoletto, G., Tamburella, F., Laurenza, L., Foti, C., Ditunno, J. F., & Molinari, M. (2011). Validity and reliability of the 10-M Walk Test and the 6-Min Walk Test in spinal cord injury patients. *Spinal Cord*, 49, 736-740.
- Sheridan, L. K., Fitzgerald, H. E., Adams, K. M., Nigg, J. T., Martel, M. M., Puttler, L. I.,... Zucker, R. A. (2005). Normative Symbol Digit Modalities Test performance in a community-based sample. *Arch Clin Neuropsych*, 21, 23-28.
- Sherrington, C., Lord, S. R., & Finch, C. F. (2004). Physical activity interventions to prevent falls among older people: update on the evidence. *J Sci Med Sport*, 7(1, Supplement), 43-51.
- Shubert, T. E., McCulloch, K., Hartman, M., & Giuliana, C. A. (2010). The effect of an exercise-based balance intervention on physical and cognitive performance for older adults: a pilot study. *J Geriatr Phys Ther*, 33, 157-164.
- Shumway-Cook, A., Brauer, S., & Woollacott, M. (2000). Predicting the probability for falls in community-dwelling older adults using the timed Up & Go Test. *Phys Ther*, 80, 896-903.
- Shumway-Cook, A., & Woollacott, M. (1995). *Motor Control: Theory and Practical Applications*. Baltimore, MD: Williams & Wilkins.
- Shumway-Cook, A., & Woollacott, M. (2000). Attentional demands and postural control: the effect of sensory context. *J Gerontol*, 55A, M10-M16.
- Smith, A. L. (1982). *Symbol Digit Modalities Test (SDMT): manual (revised)*. Los Angeles, CA: Western Psychological Services.
- Sparrow, W. A., Bradshaw, E. J., Lamoureaux, E., & Tirosh, O. (2002). Ageing effects on the attention demands of walking. *Human Movement Sci*, 21, 961-972.
- Spirduso, W., Francis, K., & MacRae, P. (2004). *Physical Dimensions of Aging (2nd ed.)*. Champaign, IL: Human Kinetics.
- Stevens, J. A., Corso, P. S., Finkelstein, E. A., & Miller, T. R. (2006). The cost of fatal and non-fatal falls among older adults. *Inj Prev*, 12, 290-295.
- Strauss, E., Sherman, E. M. S., & Spreen, O. (2006). *A Compendium of Neuropsychological Tests: Administration, Norms, And Commentary (3rd ed.)*. New York, NY: Oxford University Press.
- Tinetti, M. E., Speechley, M., & Ginter, R. N. (1988). Risk factors for falls among elderly persons living in the community. *N Engl J Med*, 319, 1701-1707.
- Tinetti, M. E., & Speechley, M. (1989). Prevention of falls among the elderly. *N Engl J Med*, 320, 1055-1059.

- Topper, A.K., Make, B.E., & Holliday, P.H. (1993). Are activity based assessments of balance and gait in the elderly predictive of risk of falling and/or type of fall. *J Am Geriatr Soc*, 41, 479-487.
- UNC Institute on Aging. (2008). Aging Demographics in NC. Retrieved from: <http://www.aging.unc.edu/infocenter/data/CensusBureauDataforNC.pdf>. (Last accessed on June 14, 2012).
- UNC Institute on Aging (2011). Quick Facts about Aging in NC. Retrieved from: <http://www.aging.unc.edu/infocenter/data/quickfacts.html>. (Last accessed on June 14, 2012).
- U.S. Census Bureau. (2011). Facts for Features: Older Americans Month: May 2011. Retrieved from http://www.census.gov/newsroom/releases/archives/facts_for_features_special_editions/cb11-ff08.html. (Last accessed on June 14, 2012).
- Vellas, B. J., Wayne, S. J., Garry, P. J., & Baumgartner, R. N. (1998). A two-year longitudinal study for falls in 482 community-dwelling elderly adults. *J Gerontol Med Sci*, 53A(4), M264-M274.
- Vellas, B. J., Wayne, S. J., Romero, L. J., Baumgartner, R. N., & Garry, P. J. (1997a). Fear of falling and restriction of mobility in elderly fallers. *Age Ageing*, 26(3), 189-193. doi: 10.1093/ageing/26.3.189
- Vellas, B. J., Wayne, S. J., Romero, L., Baumgartner, R. N., Rubenstein, L. Z., & Garry, P. J. (1997b). One-legged balance is an important predictor of injurious falls in older persons. *J Am Geriatr Soc*, 45(6), 735-738.
- Whitney, S. L., Marchetti, G. F., Morris, L. O., & Sparto, P. J. (2007). The reliability and validity of the four square step test for people with balance deficits secondary to a vestibular disorder. *Arch Phys Med Rehabil*, 88, 99-104. doi:10.1016/j.apmr.2006.10.027
- World Health Organization (2010). Falls [Fact sheet]. Retrieved from <http://www.who.int/mediacentre/factsheets/fs344/en/>. (Last accessed on June 14, 2012).